IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of	:	
Satoshi OGATA et al.	:	Group Art Unit: 1723
Serial No.: 09/600,203	:	
Filed: August 9, 2000	:	Examiner: M. SAVAGE
For: FILTER CARTRIDGE		

DECLARATION UNDER 37 C.F.R. § 1.132

Honorable Commissioner of Patents and Trademarks
Washington, D.C. 20231

Sir:

I, Osamu YAMAGUCHI, a Japanese citizen of 251, Tateiri-cho, Moriyama-shi, Shiga-ken, Japan, declare:

That I finished the study on engineering research in a graduate course of Tokushima University in March of 1994;

That I have been employed by CHISSO CORPORATION of Kitaku, Osaka, Japan, the Assignee of the above-identified U.S. patent application, and I have been engaged in research and development on polypropylene molded products, mainly on polypropylene filters from April 1994 up to now;

That I am a joint inventor of the invention disclosed in the above-identified U.S. patent application, and hence, I am fully familiar therewith; and

That in order to show distinction between the claimed subject matter and the reference (US 6,090,731) cited in the examination of the above-identified U.S. patent application, a comparative experiment was conducted under

my supervision as follows.

1. Comparative Experiment

A comparative experiment was conducted so as to compare a filter cartridge of US 6,090,731 (Pike et al.) with that of the present invention. That is, the same filter cartridges as those used in the Examples 4 and 11 were examined on the filter performance almost the same experimental conditions as those of Pike's. Then, the obtained data are compared with those described in Pike's specification to know a difference in performance of the respective filter. The detailed test condition is as follows:

The same testing machine for filtering performance as used in the Examples was used for the comparative experiment. The filter cartridge for testing was weighed in advance. 1200 ml of ion exchanged water and 1 g of AC fine test particles were introduced into the tank of the testing machine followed by stirring the mixture in order to avoid sedimentation of the testing particles. After the filter cartridge was installed to the housing, the liquid in the tank was passed through the filter cartridge by pumping. The liquid through the filter cartridge was discharged to the outside of the system without being introduced into the tank again. After all of the liquid was passed through, the filter was taken out of the housing to dry in an oven at 90°C for 12 hours followed by weighed. The weight difference of the filter cartridge of after and before the test was determined to be the amount of the trapped testing particles. The initial trapping efficiency was calculated according to the following equation.

(Initial Trapping Efficiency)=(Amount of Trapped Testing Particles)/(Amount of Added Testing Particles)

Further, filtration life was measured according to the same method as that of the present application except

that the addition rate of the cake was 1 g/5 min. All of the test conditions were almost identical with those of Pike's.

2. Result and Discussion

The results are shown in the following Table.

Table

Filter	Initial Trapping Efficiency (%)	Filter Life (min.)
Ex.4 in the present application	44	160
Ex.11 in the present application	46	165
Ex.1 in Pike's	19*1	24.7*1
Ex.2 in Pike's	23*1	12.8*1
Ex.3 in Pike's	19*1	13.9*1
Ex.4 in Pike's	32*1	2.3*1
Ex.5 in Pike's	49*1	0.8*1

*1: reproduced from Pike's specification.

The filter cartridges of Ex.4 and 11 are those produced by winding slit continuous fiber nonwoven around a perforated cylinder in a twill form. Accordingly, the filters have a larger filtration life in comparison with those of Pike's (sheet filters). For instance, the filter of Ex.11 in the present invention has almost an identical initial trapping efficiency with that of Ex.5 in Pike's, however, it has a filter life of as long as 200 times with that of Ex.5. This remarkable difference in performance is due to that of the field applied. This result shows there must be meaningless to discuss filters of different application fields with the same scale of measure.

I further declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

This 16th day of August, 2002

Osamu Yamaguchi

Osamu YAMAGUCHI

ISBN 1 85617 078 0

Other books in this series include:
Hydraulic Handbook
Seals and Sealing Handbook
Handbook of Hose, Pipes, Couplings and Fittings
Handbook of Power Cylinders, Valves and Controls
Pneumatic Handbook
Pumping Manual
Pump Users' Handbook
Submersible Pumps and their Applications
Centrifugal Pumps
Handbook of Valves, Piping and Pipelines
Handbook of Fluid Flowmetering
Handbook of Noise and Vibration Control
Handbook of Mechanical Power Drives
Industrial Fasteners Handbook
Handbook of Downstream Processing
Geotextiles and Geomembranes Manual
Handbook of Cosmetic Science and Technology

Published by
Elsevier Advanced Technology
Mayfield House, 256 Banbury Road, Oxford OX2 7DH, UK
Tel 010 44 (0) 865-512242
Fax 010 44 (0) 865-310981

FILTERS and FILTRATION HANDBOOK

3rd Edition

Christopher Dickenson, FBIM

ELSEVIER
ADVANCED
TECHNOLOGY

Surface and Depth Filtration

THE BASIS of the working of a 'mechanical' filter is that the *filter medium* or *septum* works as a porous screen, removing and retaining particles too large to pass through the openings which provide the porosity, but allowing the 'carrier' fluid to pass. Particles are collected on individual fibres by numerous mechanisms. The most important of these are *direct interception, inertial impaction* and *diffusion*. Figure 1 shows single fibre collection mechanisms.

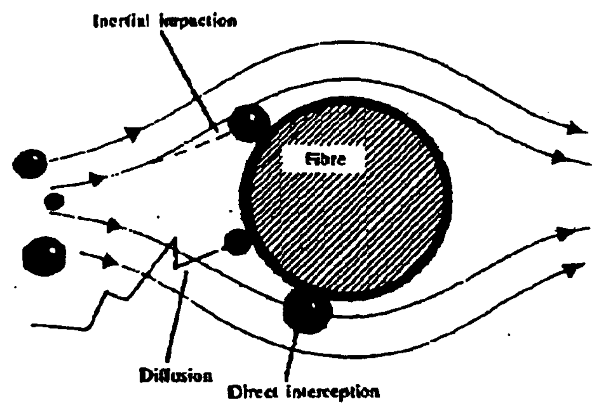


Figure 1
Particle collection mechanisms.

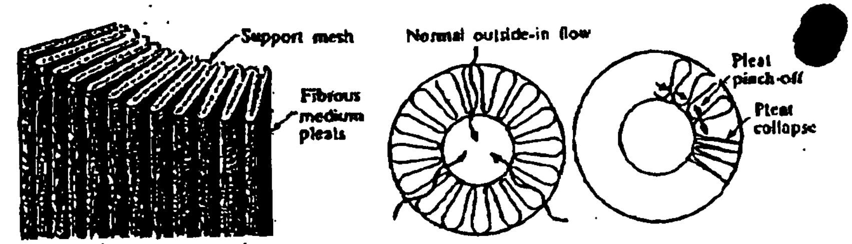
Direct interception occurs when a particle or droplet collides head-on with one of the fibres.

Inertial impaction results if a particle or droplet in the airstream fails to negotiate the tortuous path presented by the random fibres in the filter bed, collides with and adheres to a fibre.

Diffusion occurs when extremely small aerosols and particles wander in,

'Brownian Motion' within the flow pattern of the airstream, so enhancing their chances of colliding with each other and with fibres forming the filter medium.

The simplest type of mechanical filter is one providing *surface retention* – eg. a simple screen which is generally satisfactory for simple straining and filtering duties, and can also have the advantage of being readily cleanable. Dirt retention is directly related to surface area, so surface filter media are commonly fabricated in pleated form for extended area. Pleating can also considerably increase the strength of the filter, especially with paper filters.



Typical pleated paper element. A support mesh may be incorporated to prevent pinch-off or pleat collapse.

Surface filtration

Surface filtration, also called surface straining, works largely by direct interception. Particles larger than the pore size of the medium are stopped at the upstream surface of the filter; their size prevents them from entering and/or passing through the pores or openings. Adsorptive forces, though present, are small in magnitude; surface type media are not perfectly smooth on their upstream surfaces, nor are their pores perfectly uniform in shape or direction. Thus some depth filtration can take place and can have a profound effect on the filtration characteristics and life of a surface filter.

When most surface-type filters are exposed to the flow of contaminated fluid, two effects start to take place almost immediately:

(i) A gradual reduction in the effective pore size of the medium, as some of the pores become partially blocked by particles, so the filter starts to become 'finer', *ie* more efficient in removing fine particles. This can be caused by the retention of extremely small particles within the pores by adsorptive forces. (Figure 2a).

It can also occur due to the partial intrusion of soft, deformable particles into the pores, acting under the forces generated by fluid flow, so that those pores are effectively reduced in size. Deformable particles have the ability to conform more closely to the shape of flow-passages, thus blocking them to a greater degree than do hard particles. They can form a slime or gel that can completely clog a filter.

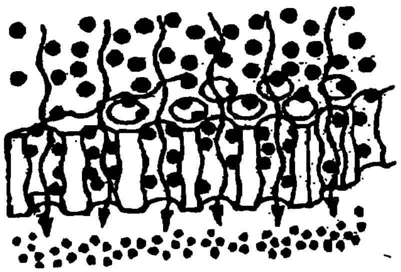


Figure 2a
Blocking action of fine particles retained by surface filter.

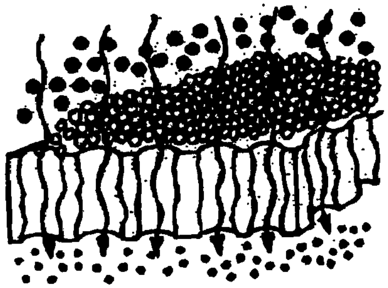


Figure 2b
Cake build-up on surface type filter.

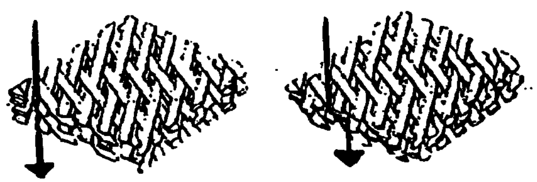
(ii) A 'cake' or bed (thick layer) of trapped particles starts to build on the surface of the medium, itself forming a filter which, by the same clogging mechanism noted previously, becomes progressively finer as operating time continues. (Figure 2b).

Surface filtration media

Surface filtration media are of three broad types:

1. Screen type filters

A thin, essentially two-dimensional structure, with a series of uniform pores through it.



Straight-through (for 75 μm up). Two layers of straight-through mesh as wound.

Zig-zag (for 2 to 75 μm filtration). Two layers of zig-zag mesh, as wound.

Examples of different flow paths provided by flat wire mesh filter elements.

Generally made of metal or plastic, screens are of the following forms:

(a) *Woven fibre* – only woven-screen types over approximately 25 micrometres pore-size can reasonably be cleaned; other types cannot be cleaned or require expensive equipment and considerable time and labour.

A significant characteristic of a woven medium is the degree of its ability to retain its original configuration – as woven – during the subsequent manufacturing processes and service life, especially under high loads. If the fibres shift, larger than planned pores may be created, thus degrading the filtration rating on the medium.

Some manufacturers sinter this type of medium with the aim of stabilising it by fusing the strands together at their interstices. The necessity for this added processing has not been completely proven.

(b) *Etched sheet* – in which the pores are produced by chemical or electrolytic processes.

(c) *Sintered powder* – thin membrane-like version of porous media as desc earlier.

(d) *Cast membrane* – a film of cast polymeric plastic in which pores are produced by chemical leaching, photo-etching or atomic bombardment.

Cast membranes are normally used only when true micro-filtration is required. High, clean pressure drop and cost, plus low dirt-capacity of membrane filters generally discourage their use in fluid power applications. (See also chapter on *Membranes*.)

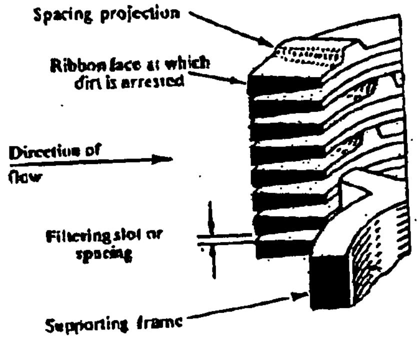
2. Edge-type filters

Edge-type filters involve the use of cartridge type elements with flow directed from the outside inwards, but the element is composed of a stack of discs or washers of paper, felt, plastic or metal clamped together in compression. Flow takes place from the edge inwards between the discs which may be in intimate contact in the case of non-rigid disc materials, or through the controlled clearance space between individual discs provided by spacing washers.

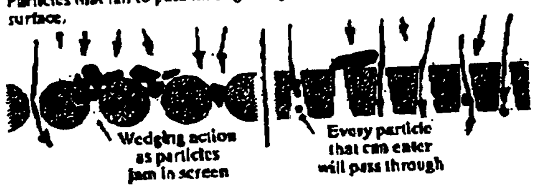
Such a construction has the advantage that the collected contaminant can be scraped from the upstream surface more easily and completely than it can from a screen and this cleaning can be performed during operation of the In addition, this type can be manufactured with inherent self-cleaning properties, so that cake build-up on the upstream surface can be virtually eliminated.

An edge-type filter element employing stacked paper discs is shown in Figure 3. The pack is held under compression by springs at the top of the assembly, so that the liquid undergoing filtration can only pass through the minute interstices between the discs in layers of near-molecular thickness. Virtually all solid impurities are, in fact, left on the edge of the discs since such an element can be capable of yielding an absolute cut-off of 1 μm or less.

A further property of such an edge filter employing unimpregnated paper discs is that it can trap and retain finely dispersed water in fuels, oils, or similar fluids. It is even possible to remove dissolved water by the provision of moderate heat and vacuum. The presence of water will, however, substantially increase the back-pressure of the filter due to the swelling of the discs, further restricting the clearance space available for flow. This can, if necessary, be used to operate a warning device that water is present in the fluid being filtered.



Tapered flow paths in a metal-edge element prevents clogging. Particles that fail to pass through may fall off or can be scraped off the surface.



Metal edge-type filter.

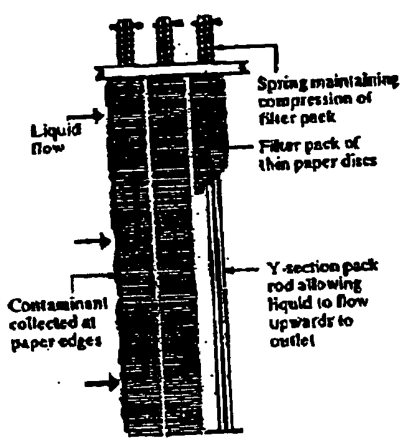


Figure 3
Stacked disc edge-type filter.

It will also be appreciated that whilst the performance of such a paper element is often better than that of a pleated paper element, its normal resistance, and thus back-pressure, is very much higher, or, size for size, its capacity is appreciably less. On the other hand it is one of the best types of filters for removing very fine solids from liquids – even colloidal graphite from oils – it is virtually immune to the effects of shock pressure, and element life is long with a minimum of maintenance requirements. Cleaning can usually be accomplished quickly and efficiently by a reverse flow of compressed air. The ultra-fine filtering properties may inhibit its use for particular applications due to the build-up of ul fine solids, restricting flow where very fine, frequent cleaning is impractic particular example is its unsuitability for use as a bypass filter for engine lu cating oil systems employing detergent oils.

3. Stacked disc filters

A stacked disc filter employs individual discs which are stacked over a perforated inner tube, with intermediate spacing washers. Flow is between, and subsequently through, the filter discs and into the inner tube. The discs are typically of composite construction, *eg* the face of the disc formed by a fine metal wire screen with a further back-up screen to provide effective use of the full filtration area; in the centre of the pack is a fitted separator to provide radial passageways for flow into the central perforated tube. The complete disc assembly is then held together by inner and outer binding rings.

Performance is nominally that of the mesh elements or filter screen apertures, typical standard openings being from 0.25 to 0.025 mm (0.01 down to 0.001 in), equivalent to ratings of approximately 250 μm and 25 μm respectively. With this form of construction, however, performance materially improves as dirt collects in the screen, providing increasingly finer filtration.

This particular form of filter is an aperture, rather than an edge-type, with depth of filtering restricted to the depth of the face screen and back-up scree provides a large surface area in a compact volume and low pressure drop.

Depth filtration

The other basic type of mechanical filter employs a medium with a significant amount of thickness providing *filtering in depth*. The mechanism of filtering then becomes much more complex. The path through the filter is much longer and random, providing greater possibility for both direct interception and dirt retention. Retention efficiency is achieved by means of a series of low efficiency particle captures. In general, larger particles will tend to be trapped in the surface layers, with the finer particles trapped by succeeding layers. If necessary, the structure of the filter can be density graded. This has a particular advantage where the particle sizes of the contaminant are widely distributed; less so if they are of more or less uniform size where a surface filter may be equally effective. Also, of course, filtering in depth will give a higher pressure drop than a surface filter.

The overall performance of a *depth-type filter*, however, can be better than that given by its purely mechanical action of direct interception. The inertia of particles impinging directly on to the filter medium may generate absorptive surface forces, and Brownian movement effects may be present with fine particles, again developing absorptive retention. As a result, the depth filter may trap and retain particles finer than that provided by pure mechanical filtration alone.

Brownian movement applies only to particles of about 1 µm in size or less, causing such particles to diffuse through the filter medium regardless of fluid flow, where they are likely to be retained by adsorptive forces. This phenomenon is most marked where the fluid carrier is a dry gas (the dryer the gas the more powerful the electrostatic adsorptive forces) and least marked with higher viscosity liquids.

Depth-type media

The ideal depth-type filter medium has increasingly dense layers from the outside (upstream) to the inside (downstream) side – Figure 4. Such a graded structure provides an increasing chance of finer particles being trapped on their passage through the filter. Practical depth-type filters are made from media which may be generally categorised as:

(i) Fibrous.
(ii) Porous.
(iii) Cake-like.

Figure 4
Graded depth type filter compared with surface filter.

Fibrous media comprise a layer, or mat, of numerous very fine fibres, of diameters ranging from 0.5 to 30 µm, depending on the material. These fibres are randomly oriented to each other, intermixed and intertwined so that they create numerous tortuous flow-passages or pores in which the particles are trapped and held by the mechanisms described previously.

The fibrous materials most commonly used are:

Polymeric materials; Cellulose; Cotton; Micro glass-fibre; Synthetics, (*eg* rayon, polypropylene).

Relative efficiencies of these media types are a function of fibre diameter, the narrower the fibres, the closer they can be compacted. The result is that smaller diameter fibres have smaller flow paths. Micro glass-fibre is smaller in diameter than cellulose and has therefore, a better filtration efficiency.

Typically, the layer is 0.25 to 2 mm (0.010 to 0.080 in) thick and is impregnated with resin (phenolic, epoxy or acrylate) to bind it together. The maintenance of stable structure, including pore size, and therefore of stable filtration characteristics throughout the medium's service life, referred to as *filter integrity*, is a function of the fibre-binding system.

Fibrous filter media are used for the collection of sub-micrometre particles in clear air environments. Filter media made from electret fibres have an structure and are capable of achieving a high particle collection efficiency without incurring a high pressure drop.

Electrets are permanently charged dielectrics made in most cases from polymeric materials that generally permit substantial sub-micrometre size particle penetration.

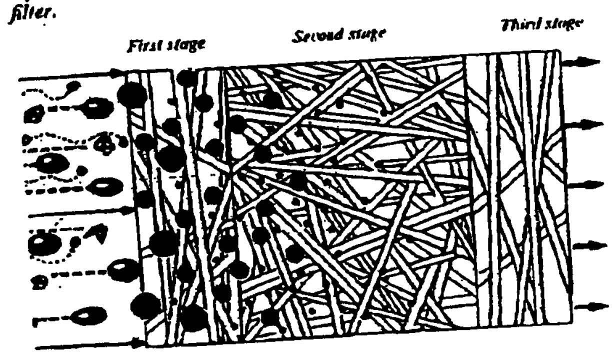
Contaminants such as viruses or bacteria must be removed from air supplied to operating theatres in hospitals and the need for near dust-free air is important for the manufacture of microelectronic equipment. Electret filters can provide a solution to the efficient cleaning of air and gases in these environments.

Binder-free media

The introduction of a three-dimensional layered binder-free *borosilicate microfibre* webbing has assumed considerable importance in depth filtration, particularly in relation to the filtration of compressed air and gases.

The characteristic feature of this material is that the fibres are 'welded' together by temperature and pressure.

By utilising direct interception, inertial impaction and diffusion, liquid and solid particles down to 0.01 µm are retained by the filter.



Advantages claimed for this type of fibrous media are:

1. If the fibre diameter is the same throughout, the void volume increases. This automatically reduces pressure loss, increases retention and can prolong filter life.

2. The fibres are incorporated into the filter material in their natural state - and their retention properties are unaffected by the insulating acrylate layer.

3. The fibre diameter starts off the same, and an insert of acrylate increases it. However, the diameter reduces exponentially when the degree of retention is measured (*sic*).

4. The pure fibre is inert, chemically, biochemically and biologically inactive and neutral. Glass can actually only be attacked by hydrofluoric acid and the strongest of alkalis. The resistance of fibres with binders is determined by the chemical resistance of the binder.

5. A fibre consisting solely of glass is resistant to temperatures up to 500°C. Binders soften at temperatures between 80 and 150°C and lose their resistance, and the basic characteristics of the filter material is thus also lost.

Porous media are similar in that they have flow pores presenting a capillary-type passage. This differs from a fibrous medium in that its parent material is solid or in the form of randomly shaped particles of roughly spherical proportions.

There are three major forms of porous media:

(i) Particles of the parent materials are cast to shape, then baked or sintered to bond them together into a self-supporting structure. Typical materials are metals, ceramics and stone.

(ii) A sheet of parent plastic materials is cast, then pores are formed by solvent evaporation, leaching, stretching, piercing or nuclear bombardment.

(iii) Porous media are formed by the foaming of plastic materials, typically polyurethanes.

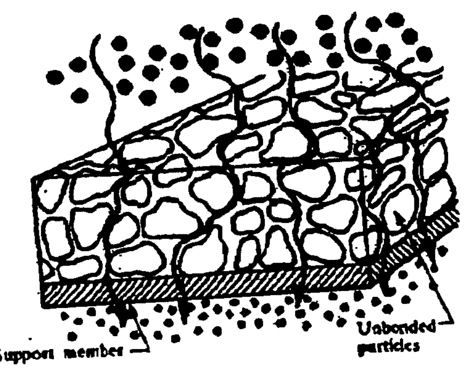


Figure 5
Cake type filter medium.

Cake-type media are more limited in application and generally employe bed-type filtration for removal of solids in significant bulk. (Figure 5).

They comprise a layer or bed of separate, loose, discrete particles formed a 'cake' on a supporting screen or mesh, usually by the action of fluid flow. voids between the particles form the pores and flow passages required fo tration. Binding materials are not used to bond the particles to each other.

Typical materials used to form the cake are:
Diatomaceous earth; Sand; Clays; Wood fibres; Cotton fibres.

This loose bed construction makes them generally unsuitable for fluid applications, where stability, compactness and resistance to vibration are of p importance. The characteristic of recirculating some of the discrete part through the system, until the cake is formed, is a definite deterrent to use in power systems.